iSCWO: Destruction of Hazardous Wastes

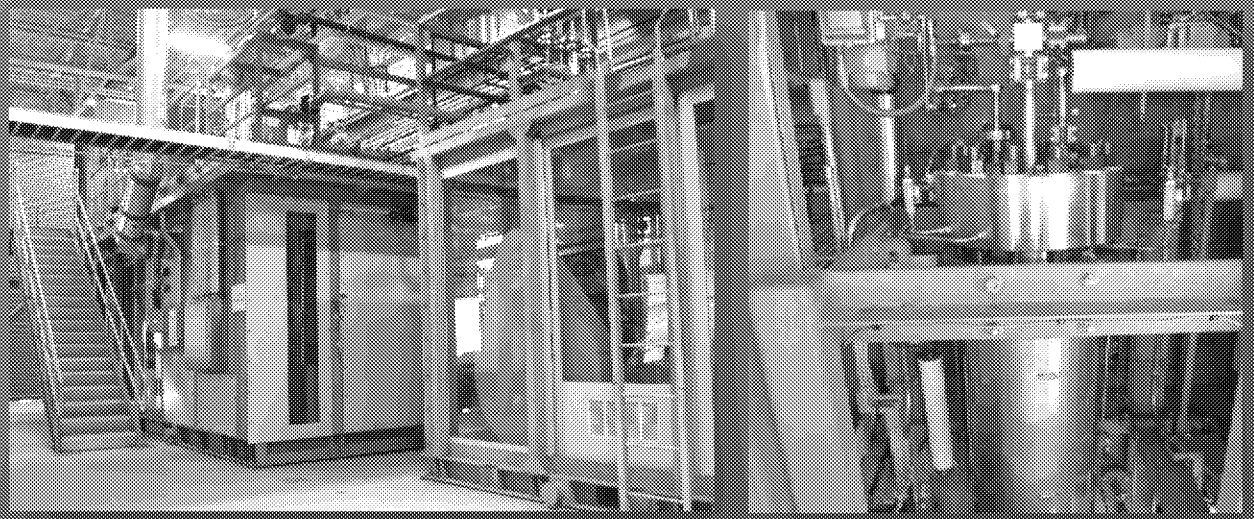
June 3, 2015

GENERAL ATOMICS

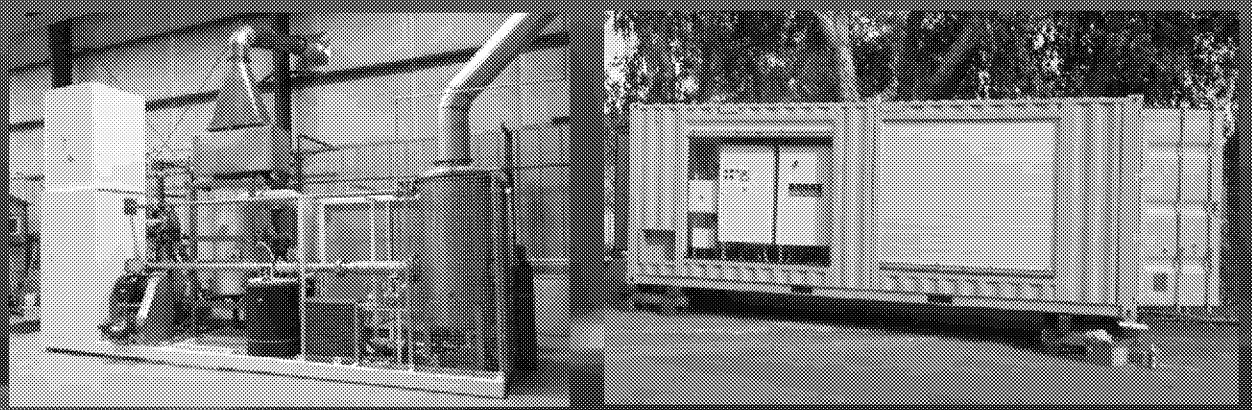
Transitioning High-Risk R&D into Operational Systems

Supercritical Water Oxidation

- Developed for safe treatment of military wastes
- Highest performance hazardous waste disposal system
- Transitioned to commercial applications



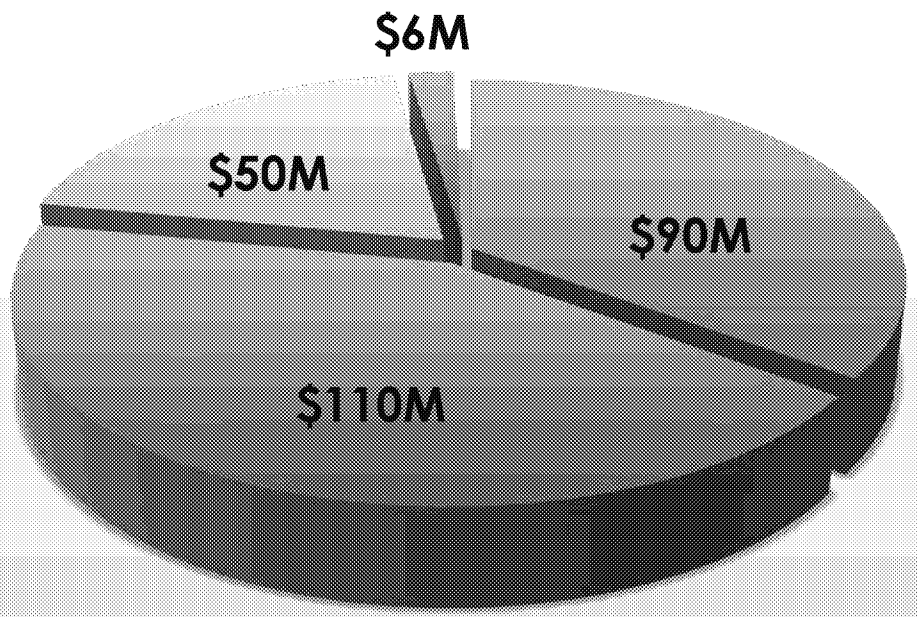
Operational system for destruction of chemical agents for the U.S. Army



Commercial system for European customer

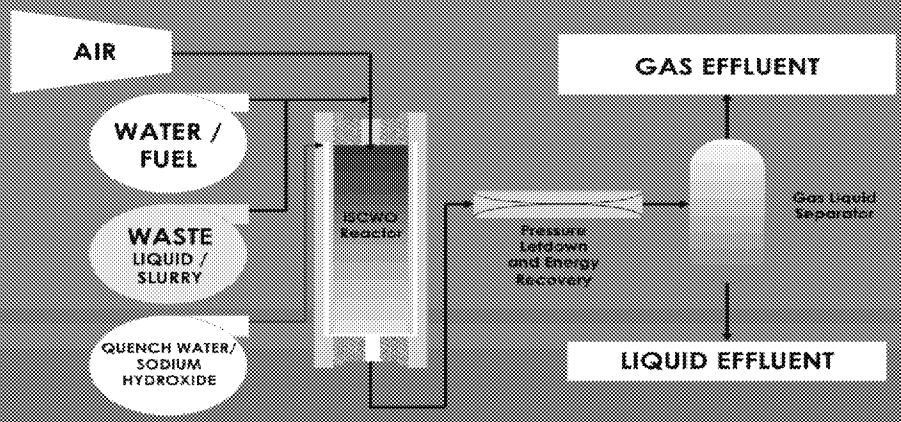
GA Developing SCWO Since 1992

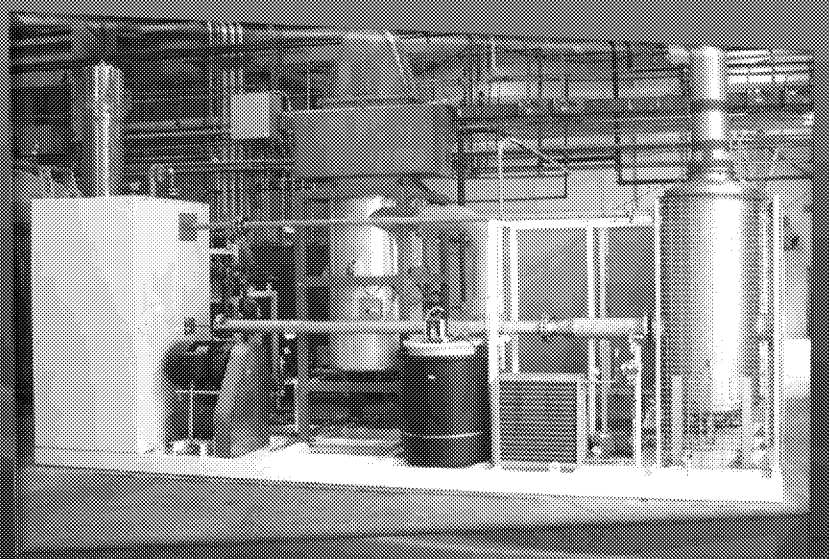
- Development and testing of SCWO at GA ($90M)
- Delivered Energetics Hydrolysis/ SCWO system to BGCAPP site on schedule and within budget ($110M)
- Development and delivery of iSCWO systems to US Government ($50M)
- Other ($6M)



GA and US Government investment in SCWO/iSCWO totals more than $250M

Technical & Cost Advantages





- Cost competitive with incineration
- No airborne particulates
- Very low nitrogen oxide, sulfur oxide, and total organic carbon content
- Clean water by-product requiring little or no post-treatment
- Waste stream testing service before purchase

Rapid, complete organic destruction with no pollution abatement system

Customer Engagement Process

Gather Data

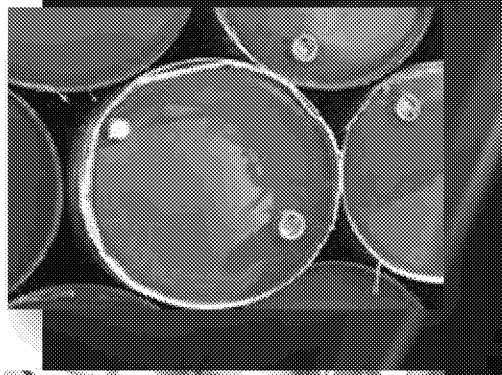
- Determine wastes' chemical composition
- Define interface, siting and schedule requirements
- Define throughput and effluent discharge requirements
- Evaluate basic CAPEX and OPEX

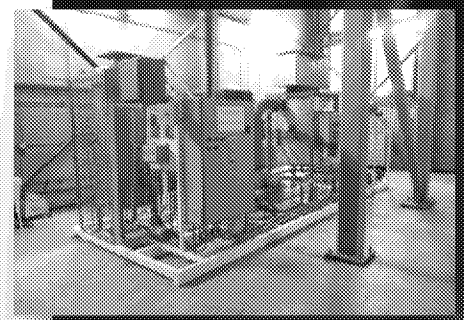
Finalize Requirements

- Decide if testing at GA is required; conduct testing if necessary
- Meet with customers to finalize requirements for RFP

Develop and Submit Proposal

- Scope of equipment supply
- Scope of work (installation, checkout/startup, support operations)
- Spare parts
- Schedule and deliverables





A Wide Range of Chemicals Successfully Treated with GA Technologies

Complex Feeds

- Activated carbon (spent)*
- Adhesives*
- Aqueous Cleaning Solution*
- AFFF
- Antifreeze*
- Aroclor 1242
- Aroclor 1254
- Aroclor 1260*
- Bacillus stearothermophilus (heat resistant spores)
- Brake fluid*
- Bran cereal
- Caprolactam wastewater
- Casein
- Chlorinated plastics (shredded)*
- Class 1.1 solid propellant*
- Class 1.3 AP-depleted solid propellant
- Coal
- Coal waste
- Corn flakes*
- Corn oil
- Corn starch
- Diesel fuel
- E. coli
- Endotoxin (pyrogen)
- Explosives/energetics/propellants (hydrolyzed RDX, TNT, Tetryl, NG, NC)*
- Fermentation byproducts*
- Fuel oil
- GB chemical agent (neat, hydrolyzed*)
- Gray water*
- Greases (mixed)*
- Human waste
- Hydraulic fluid*
- Industrial biosludge
- Ion exchange resins (styrene - divinyl benzene)
- Kerosene*
- Lube oil (molybdenum disulfide oil)*
- Malaria antigen
- Motor oil*
- Mustard chemical agent (neat, hydrolyzed*)
- Navy shore-based wastes*
- Olive oil
- Organic salts (complex mixtures)*
- Paint, paint sludges*
- Paper
- Paraffin oil
- Pesticide manufacturing wastewater
- Pharmaceutical waste*
- Photographic developer paste
- Photographic developer solutions*
- Polychlorotrifluoroethylene (PCTFE)*
- Pig manure
- Propellants (hydrolyzed)*
- Protein
- Pulp/paper mill sludge
- Sewage sludge (black water)*
- Soil contaminated with organics
- Soybean plants
- Sulfolobus acidocaldarius
- Transformer oil*
- Trimsol cutting oil*
- VX chemical agent (neat, hydrolyzed*)
- Waste oils (chlorinated and non-chlorinated)*
- Wheat straw*
- Wood fibers
- Yeast

Inorganic Substances

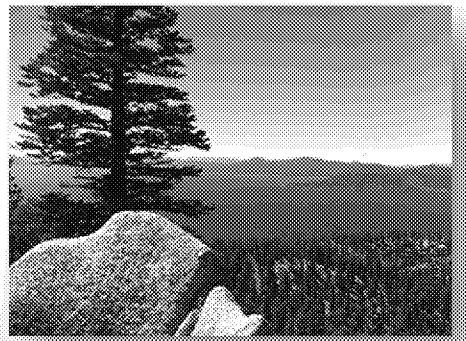
- Aluminum hydroxide*
- Aluminum metal
- Aluminum oxide sodium
- Ammonia*
- Ammonium chloride
- Ammonium nitrate*
- Ammonium nitrite*
- Ammonium perchlorate*
- Ammonium sulfate
- Ammonium sulfite*
- Boric acid
- Bromides
- Calcium carbonate
- Calcium chloride
- Calcium oxide
- Calcium phosphate
- Calcium sulfate
- Cerium chloride*
- Copper chloride
- Fluorides
- Hydrochloric acid*
- Hydrofluoric acid
- Iron chloride
- Iron oxide*
- Lead chloride*
- Lead sulfate*
- Lithium hydroxide
- Lithium sulfate
- Magnesium nitrate
- Magnesium oxide
- Magnesium phosphate
- Magnesium sulfate
- Mercuric chloride
- Molybdenum disulfide lube oil*
- Nitric acid*
- Phosphoric acid
- Potassium bicarbonate
- Potassium carbonate
- Potassium chloride
- Potassium hydroxide
- Potassium sulfate
- Silica
- Sodium bicarbonate*
- Sodium carbonate
- Sodium chloride*
- Sodium fluoride*
- Sodium hydroxide*
- Sodium nitrate
- Sodium nitrite
- Sodium phosphate*
- Sodium sulfate*
- Sodium sulfite
- Sulfur, elemental
- Sulfuric acid*
- Titanium dioxide
- Zinc chloride*
- Zinc sulfate*

Organic Chemicals

- Acetic Acid
- Acetone
- Acetylsalicylic acid(aspirin)
- Adumbran
- 4[(2-Amino-3, 5-dibromophenyl)-methylamino]cyclohexanol
- Ammonium acetate*
- Ammonium formate*
- Ammonium oxalate*
- Benzene
- Biphenyl
- Butanol*
- Calcium acetate*
- Carbon tetrachloride*
- Carboxylic acids
- Carboxymethyl cellulose
- Cellulose
- Cerium Acetate*
- Chlorinated dibenzo-p-dioxins
- 6-chloro-2,3,4,5-tetrahydro-3-methyl-1H-3-benzazepine hydrochloride
- Chlorobenzene*
- Chloroform*
- 2-Chlororphenol*
- o-Chlorotoluene*
- Cobalt acetate
- m-Cresol*
- Cyanide*
- Cyclohexane
- DDT
- Decachlorobiphenyl
- Dextrose
- Dibenzofurans
- 3,5-dibromo-NOcyclohexyl-N-methyltoluene-,2-diamine
- Dibutyl phosphate
- Dichloroacetic acid
- Dichloroanisole
- Dichlorobenzene
- 4,4-Dichlorobiphenyl
- Dichloroethylene
- Dichlorophenol
- Diethanolamine*
- Dimethylformamide*
- Dimethyl methyl phosphonate (DMMP)*
- Dimethyl sulfoxide*
- 4,6-denitro-o-cresol
- 2,4-Dinitrophenol
- Dinitrotoluene
- Dipyridamole
- Diisopropyl ethanolamine
- Diisopropyl ethylamine
- Ethanol
- Ethyl acetate*
- Ethylene chlorohydrin
- Ethylenediamine tetraacetic acid
- Ethylene glycol
- Fluorescein*
- Freon 22
- Glycerol
- Hexachlorobenzene
- Hexachlorocyclohexane
- Hexachlorocyclopentadiene
- Iron acetate*
- Isooctane
- Isopropanol*
- Lead acetate*
- Mercaptans
- Mercaptoethanol
- Methanol*
- Methyl acetate*
- Methyl cellosolve
- Methylene chloride*
- Methyl ethyl ketone
- Methylphosphonic acid (MPA)
- Monoethanolamine*
- Nitrobenzene*
- 2-nitrophenol
- 4-nitrophenol
- Nitrotoluene
- Octachlorostyrene
- Octadecanoic acid magnesium salt
- Paracetamol
- Pentachlorobenzene
- Pentachlorobenzonitrile
- Pentachlorophenol*
- Pentachloropyridine
- Phenol
- Polychlorinated biphenyls (PCB*)
- Polychlorotrifluoroethylene*
- Sodium acetate
- Sodium formate
- Sodium hexanoate
- Sodium isethionate*
- Sodium propionate
- Sucrose
- Surfactant
- Tetrachlorobenzene
- Tetrachloroethylene*
- Tetrapropylene H
- Thiodiglycol*
- Toluene
- Tributyl phosphate
- Trichlorobenzenes
- 1,1,1-Trichloroethane*
- 1,1,2-Trichloroethane*
- Trichloroethylene
- Trichlorophenol
- Trifluoroacetic acid
- 1,3,7-Trymethylxanthine
- Unsymmetrical dimethyl hydrazine
- Urea
- o-Xylene*
- Zinc acetate*

iSCWO Release Streams Meet Environmental Requirements

Waste Feed	Gas Release	Liquid Release
Energetics	O_2 depleted/CO_2 enriched air, water vapor, and small amount of N_2O; organic free	Organic-free water and sodium salts depending on energetic formulation
Cleaning Solutions	O_2 depleted/CO_2 enriched air, water vapor, and small amount of N_2O; organic free	Organic-free water and suspended metallic oxides
Organics	O_2 depleted/CO_2 enriched air and water vapor; organic free	Organic-free water
Pharmaceuticals	O_2 depleted/CO_2 enriched air and water vapor; organic free	Organic-free water and dissolved salts depending on composition of waste
Fertilizers	O_2 depleted/CO_2 enriched air, water vapor, and small amount of N_2O; organic free	Organic-free water and dissolved phosphate and sulfate salts depending on fertilizer type



iSCWO Unit Customization Level Dependent on Waste Type

No Customization	Low-Level Customization	Mid-Level Customization
Petrochemicals	Metals treatment	Coal products
Hydrocarbons	Mining runoff	Ceramic processes
Organic bases	Organics with metals	Poultry/pig/animal wastes
Organics with sulfur	Plastics	Organics with phosphorus
Dyes and Pigments	Organic acids	Rubber
Pharmaceuticals	Organics with salts	Pulp/timber processing
Energetics	System modifications	Wood processing
Paints	Salt processing	System modifications (Same as low-level plus:)
Fertilizers	Filters	Slurry grinding
	Upgraded feed pumps	Advanced salts processing
	Feed prep systems	Improved liners

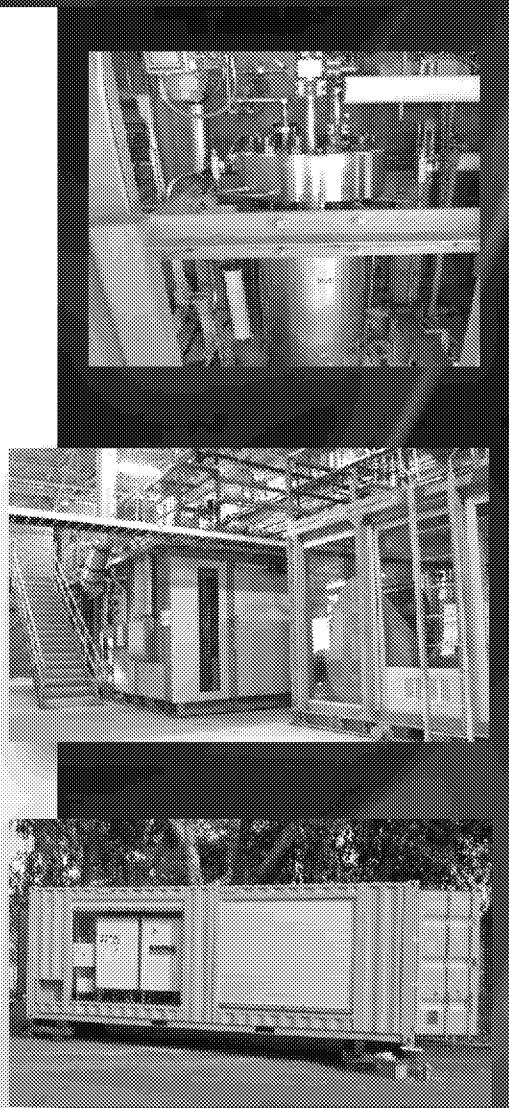
Proposed Two-Phase Implementation Program

Phase 1 : Testing and Scoping Assessment

- Identify candidate waste streams
- Define throughput and effluent discharge requirements
- Perform tests at GA
- Evaluate results
- Conduct scoping assessment to determine extent of application
- Develop business plan

Phase 2 : iSCWO Business Relationship

- GA provides all components, then assembles, programs automated controls/HMI and tests units for sale
- GA provides logistics support and training
- Possible joint venture relationship



Summary

- iSCWO is fully capable of destroying a wide range of pumpable hazardous wastes to environmental standards
- The iSCWO system is a highly competitive commercial product with wide application
- GA provides value priced waste testing capabilities for customers – know before you buy